New Empirical Evidence on "Economic Convergence"

Jianyang HU

Faculty of Economics, Cambridge University; Visiting Scholar, Harvard University.
Email:jh695@cam.ac.uk.

Abstract:

The paper studies the economic convergence of non-oil-producing countries, OECD countries and emerging markets countries with latest panel data up to 2009. The study finds that conditional convergence exists among 157 non-oil-producing countries, 28 OECD countries and 23 emerging markets, and the convergence structure differs between emerging markets and the rest of the world. Furthermore, countries that have higher growth rate and hence faster convergence generally tend to have higher openness and lower government intervention. The study reveals the insight of future global economic landscape with the ongoing convergence.

Key words: Globalization, Economic convergence, Emerging markets

1. INTRODUCTION

The important trend after World War II is the globalization of world economy. According to classical international trade theories including Ricardian comparative advantage and Heckscher-Ohlin (HO) model (Leamer, 1995; Krugman & Obstfeld, 2008), globalization benefits both developed and developing countries and improves the welfare of all involved nations. It also increases the diffusion of advanced technology and boosts global productivity and innovation (Levitt, 1999).

In the process of globalization, we empirically observe the rapid economic recovery of Western European countries in 1950s~1970s, and the miraculous emergence of emerging markets countries---NIEs in 1970s~1990s. The world economy has changed completely due to accelerating globalization after 1985, together with the boom in international trade and emerging markets, especially with the emergence of BRIC countries in 1980s~2010s. An intriguing question is whether there is natural convergence of the global economy with the globalization. It is of particular importance provided the current trend of emergence of BRIC countries. Empirical studies with robust econometric methodology and latest data can reveal insightful views for the future international economic landscape in the following decades.

Therefore, the motivation of this paper is two-fold. First, the hypothesis of convergence in the samples of non-oil-producing countries, OECD countries and emerging markets with the latest 1970-2009 data will be tested. Second, the effect of trade openness and government intervention on the growth convergence will be investigated. Proper methods of cross-section regression and panel data analysis are employed.

The study contributes to the mainstream economic growth study by systematically analyzing the convergence of emerging markets. The result shows that conditional convergence exists among all nations, and BRIC countries are converging with the OECD countries in a faster way than other non-oil producing countries, assuming the current speed of economic and population growth, and current status of openness and government intervention. The result is robust based upon analysis of latest cross-sectional and panel data (up to 2009), which reflects the recent economic development in the last decade. By comparing the world economy, OECD and emerging markets, the study reveals the insight for prediction of future world economic map. Moreover, economies with higher openness and lower government intervention generally have higher growth rate and hence faster convergence.

The paper is organized as follows. Section 2 provides the theoretical background of Solow Growth Model within neoclassical framework and past empirical studies. Section 3 shows the systematic analysis based upon cross-section and panel-data regression. Section 4 concludes.

2. THEORETICAL BACKGROUND

2.1 Related Literature

Formally, "convergence club" is defined as "the set of countries for whom growth and initial level are negatively correlated" (Chatterji, 1992). The absolute convergence in terms of per capita income is called "σ-convergence", or unconditional convergence. The alternative concept is "β-convergence" (or conditional convergence) that refers to countries converging to their own long-run steady state (Mankiw et al., 1992). There are also barriers between different convergence clubs due to saving ratio, population growth, education level and political institution etc (Dowrick, 2001).

There are two mainstream empirical research methodologies: 1) includes explanatory variables based on intuition and trial-and-error without theory. Baumol (1986) finds unconditional convergence among 17 advanced countries. Yet, Barro (1991) instead finds σ-convergence in OECD countries, but β-convergence in a broader sample. 2) is based on neoclassical economic theory. The β-convergence implied by the Solow Model is verified by Mankiw (1992, MRW henceforth). Islam (1995) also shows similar supporting evidence using panel data. Caselli (1996) then finds a higher convergence rate after correcting endogeneity by GMM. These studies mainly use 1960-1985 data constructed by Summers (1988).

Then, we extend the basic model to study the factors of trade openness and government intervention by adding new regressors of the ratio of exports plus imports to the real GDP (denoted by op_i), and government expenditure divided by the real GDP (denoted by gov_i) respectively.

2.2 Solow Neoclassical Model

Solow model is the theoretical model that supports the empirical analysis of economic convergence. Suppose the Cobb-Douglas production function is

$$Y(t)=K(t)^{\alpha}(A(t)L(t))^{1-\alpha} \quad 0<\alpha<1, \text{ where } A(t)=A(0)e^{gt}, L(t)=L(0)e^{nt},$$

then the steady-state income per effective worker is (Romer 2001)

$$\ln\hat{y}^{*}(\mathrm{t}) = \ln\left(\frac{\mathrm{Y(t)}}{\mathrm{A(t)L(t)}}\right) = \frac{\alpha}{1-\alpha}\ln(\mathrm{s}) - \frac{\alpha}{1-\alpha}\ln(\mathrm{n}+\mathrm{g}+\delta).$$

Approximating around the steady state, the convergence speed is $dln\hat{y}(t)/dt = \lambda\left(\ln\hat{y}^{*}(\mathrm{t}) - \ln\hat{y}(t)\right)$. Hence cross-section regression equation in the MRW model is

$$\begin{aligned} \Delta ln\hat{y}_i(t) &= \ln\hat{y}_i(t_2) - \ln\hat{y}_i(t_1) = \left(1-e^{-\lambda\tau}\right)(\ln\hat{y}_i^{*}(\mathrm{t}) - \ln\hat{y}_i(t_1)) \\ &= \beta_1 ln(s_i) + \beta_2 ln(n_i + g_i + \delta_i) + \gamma\, ln\,\hat{y}_i(t_1) + \varepsilon_i, \end{aligned}$$

where $\tau=t_2-t_1$, $\beta_1=(1-e^{-\lambda\tau})\alpha/(1-\alpha)$, $\beta_2=-(1-e^{-\lambda\tau})\alpha/(1-\alpha)$, $\gamma=-(1-e^{-\lambda\tau})$. It assumes countries are in their steady state in the final period. It also assumes all the explanatory variables, such as the saving ratio s_i and the population growth rate n_i, vary across countries but are constant over time. Nevertheless, capital accumulation rate g_i, capital depreciation rate δ_i are assumed to be constant and $g+\delta=0.05$ (Mankiw, 1992). Finally, the common convergence rate is given by $\lambda=-ln(1-\gamma)/\tau$ for all the countries in the sample.

Although the MRW model is the benchmark, it is difficult to measure "effective labour". If we assume a constant relation between population and labour force, the steady-state income per capita is

$$\ln y^*(t) = \ln\left(\frac{Y(t)}{N(t)}\right) = c + \ln A(0) + g * t + \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta)$$

Assuming $lnA_i(0)=constant+v_i$, then the multiplicative component (v_i) included in the initial technology $A_i(0)$ reflects not just cross-country technology, but also all the other unobserved country-specific characteristics that are constant over time, including resource endowments, climate, culture, institutions and so on (Islam, 1995). Thereby, omitting the unobserved effects will not only make the estimators imprecise, but may also induce the problem of endogeneity and biasness if v_i is correlated with other explanatory variables. Due to the comprehensive scope of unobserved features, it is difficult to find proper instruments. A better approach is to use panel-data analysis to partial out country and year fixed-effects (Islam, 1995; Caselli, 1996).

$$\Delta \ln y_{it} = \gamma \ln y_{it-\tau} + \beta_1 ln(s_{it}) + \beta_2 ln(n_{it} + g_{it} + \delta_{it}) + \eta_t + \mu_i + \varepsilon_{it}$$

where $\eta_t=g(t-e^{-\lambda\tau}(t-\tau))$, $\mu_i=(1-e^{-\lambda\tau})lnA_i(0)$.

3. EMPIRICAL STUDIES

3.1. Data and Samples

The cross-country yearly data used are published by *Penn World Table*[1], which includes 190 countries and regions with multiple periods from 1970 to 2009. 26 countries with missing data are removed. If they are random and exogenous, then it does not affect the general results and implications (Wooldridge, 2009).

The most comprehensive sample is 157 non-oil-producing countries. The second sample includes 28 OECD countries, which contains more credible data. The third sample includes 23 emerging markets[2] tracked by *The Economist*. In cross-section analysis, all data are averaged over 1970-2009 (Mankiw, 1992). In panel-data analysis, data are averaged for every 5-year span to smooth yearly disturbance that may loom large in yearly time spans (Islam, 1995).

[1] http://pwt.econ.upenn.edu/php_site/pwt_index.php

[2] List of 23 Emerging Markets: Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Israel, Malaysia, Mexico, Morocco, Nigeria, Peru, Philippines, Poland, South Africa, South Korea, Taiwan, Thailand, Turkey, Hong Kong, Singapore. Please refer to http://en.wikipedia.org/wiki/Emerging_markets.

TABLE I: Summary of Cross-Section Data

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max
$ln(y_{05})$-$ln(y_{70})$	157	.560082	.6901802	-1.649783	2.730117
y_{70}	157	12303.62	13865.5	359.8494	72921
n	157	.0182685	.0101571	-.0046548	.054828
s	157	.2203267	.1175429	.0350326	.6155559
op	157	.7626709	.4553303	.0440396	3.264528
gov	157	.1965764	.105183	.043415	.6636384

Note: y_{70} is the real GDP per capita in 1970, s is the saving ratio to the real GDP (assumed to be equal to the investment ratio), n is the exponential growth rate of total population. op is the measure of openness of the country (the ratio of exports plus imports to the real GDP). gov is the degree of government intervention (government expenditure divided by the real GDP).

The summary in Table I shows that all variables have sufficient variance that meets the assumption of "sample variation in the explanatory variable".

3.2 Cross-Section Analysis

The unit-root test across the section shows no evidence of stochastic trend in the data, which prevents spurious regression.

TABLE II
Cross-Section Test for Unconditional and Conditional Convergence, 1970-2009
Dependent Variable is log difference GDP per capita 1970-2009: $ln(y_{05})$-$ln(y_{70})$

Sample	NONOIL		OECD		Emerging Markets (EM)	
	(1)	(2)	(3)	(4)	(5)	(6)
$ln(y_{70})$	-0.032	-0.201***	-0.275*	-0.292**	-0.262	-0.432**
	(0.052)	(0.048)	(0.101)	(0.088)	(0.182)	(0.118)
$ln(s)$		0.390***		0.986***		1.175***
		(0.087)		(0.250)		(0.224)
$ln(n+g+\delta)$		-1.615***		-0.074		-0.875
		(0.366)		(0.519)		(0.832)
$constant$	0.825	-1.488	3.405**	4.608**	3.153*	4.003
	(0.431)	(1.031)	(0.951)	(1.478)	(1.492)	(2.510)
N	157	157	28	28	23	23
R^2	0.002	0.313	0.222	0.528	0.089	0.677
$Wald\ test$		8.87		2.41		0.11
		(0.003)		(0.133)		(0.7477)
$Implied\ \lambda$	0.00130	0.00898	0.01286	0.01381	0.01215	0.02263

Note: (1) standard errors in parentheses;
*(2) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;*

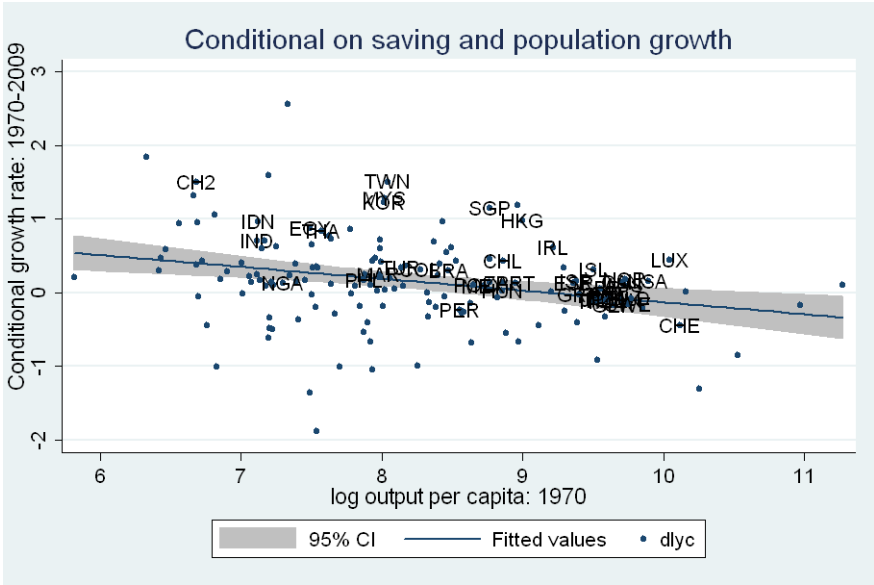
(3) H_0: $\beta_1+\beta_2=0$ in the Wald test. F statistics is reported with p-value in parentheses;

(4) Implied convergence rate $\lambda=-ln(1-\gamma)/25$.

The first finding in Table II is that the coefficients of $ln(y_{70})$ are all negative, which is the sign of unconditional convergence; yet, they are insignificant even at 90% confidence level except for OECD countries. Thereby, we reject the relation between growth and initial income level for non-oil countries and emerging markets, except OECD countries. The result coincides with Baumol (1986) and Barro (1991).

Second, conditional convergence, which is significant at the 0.05 level, is exhibited in Figure I. Take the OECD countries for example. The coefficient of $ln(y_{70})$, $\gamma_{OECD}=-0.292$, provides the partial effect given the ceteris paribus condition. That is, given fixed value of saving ratio and population growth for all OECD countries, if the real income per capita of one OECD country is 1% higher than another one, then its growth rate over 1970-2009 will be *0.292*0.01=0.292%* less; and if the income gap is 100%, then the growth rate over 1970-2009 will be *ln(2)*0.292=20.24%* less for the richer country, or 0.81% per year, which is not trivial.

Figure I: Scatter Plot of $ln(y_{70})$ versus $ln(y_{05})$-$ln(y_{70})$



Third, after controlling the effect of saving ratio, population growth, capital accumulation and depreciation, we find the convergence speed is $\lambda_{EM}>\lambda_{OECD}>\lambda_{NONOIL}$. Particularly, $\lambda_{EM}=0.023$, which implies that the economy moves halfway to its steady state (denoted as hl_{EM}) in $hl_{EM}=-ln(0.5)/\lambda$=30.6 years, whereas hl_{OECD}=50.2 years and hl_{NONOIL}=77.2 years.

Fourth, the coefficients of saving and population growth have expected signs. But we reject the null hypothesis for $\beta_1+\beta_2=0$ at the significance level of 5% for all samples through Wald test.

That is, β_1 and β_2 have different magnitudes. Thus, the empirical evidence for the Solow model is mixed. Nevertheless, these factors, as useful control variables, greatly improve R^2.

To study whether the convergence rates of OECD and EM are different from non-oil countries, we could use the dummy to extract the ceteris paribus effect. The dummies for OECD and EM are denoted as od_i, em_i respectively.

$$\Delta \ln \hat{y}_i = -1.18 + 1.63 od_i - 0.21 \ln \hat{y}_i - 0.16\, od_i \ln \hat{y}_i + 0.39 \ln(s_i) - 1.52 \ln(n_i + 0.05) + \varepsilon_{it}$$
$$(1.191) \quad (2.086) \quad (0.054) \quad (0.224) \quad (0.088) \quad (0.398)$$

$$\Delta \ln \hat{y}_i = -1.84 + 1.77 em_i - 0.19 \ln \hat{y}_i - 0.16\, em_i \ln \hat{y}_i + 0.36 \ln(s_i) - 1.65 \ln(n_i + 0.05) + \varepsilon_{it}$$
$$(0.993) \quad (1.425) \quad (0.048) \quad (0.174) \quad (0.084) \quad (0.352)$$

The intercept dummies control country-specific factors that implicitly affect the growth rate of OECD and EM countries. The partial effect of being an emerging market at average income level is 1.77-0.19*$\overline{\ln \hat{y}_i}$=1.77-0.19*8.16=0.22, namely the growth rate of emerging markets over 1970-2009 will be 22% higher, or 0.88% higher per year assuming all other factors are equal and fixed. The negative sign of interaction terms shows OECD and EM countries on average converge faster compared to other non-oil countries. Yet, the coefficient of dummies and interaction terms are insignificant due to possible multicollinearity. On the contrary, estimation in different samples in Table II are more precise, which is equivalent to adding intercept dummy and slope dummy for every variable.

TABLE III
Cross-Section Test for Conditional Convergence, 1970-2009
Dependent Variable is log difference GDP per capita 1970-2009: $ln(y_{05})$-$ln(y_{70})$

Sample	NONOIL		OECD		EM	
	(1)	(2)	(3)	(4)	(5)	(6)
$ln(y_{70})$	-0.205***	-0.220***	-0.366***	-0.286**	-0.473***	-0.417**
	(0.048)	(0.048)	(0.082)	(0.098)	(0.111)	(0.119)
$ln(s)$	0.323***	0.429***	0.933***	1.013**	0.886**	1.126***
	(0.092)	(0.087)	(0.222)	(0.317)	(0.250)	(0.230)
$ln(n+g+\delta)$	-1.754***	-1.487***	-0.093	-0.024	-1.523	-1.184
	(0.368)	(0.363)	(0.459)	(0.632)	(0.829)	(0.889)
op	0.224*		0.284*		0.282	
	(0.108)		(0.102)		(0.136)	
gov		-1.142*		0.215		-1.382
		(0.446)		(1.486)		(1.400)
constant	-2.117*	-0.700	5.031***	4.701**	1.948	3.187
	(1.063)	(1.058)	(1.316)	(1.639)	(2.521)	(2.644)
N	157	157	28	28	23	23
R^2	0.332	0.341	0.647	0.529	0.739	0.694
Hetero-	1.36	0.49	0.12	1.34	0.33	0.00
test	(0.243)	(0.486)	(0.728)	(0.246)	(0.5629)	(0.991)
Implied λ	0.00918	0.00994	0.01823	0.01347	0.02562	0.02158

Note: *(1) standard errors in parentheses;*

(2) $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$;

(3) H_0*: SD(*ε_i*) is constant in the Breusch-Pagan heteroscedasticity test.* χ^2 *statistics is reported with p-value in parentheses;*

(4) Implied convergence rate $\lambda=-ln(1-\gamma)/25$.

In table III, the convergence after controlling two extra effects is analyzed: openness and government intervention. Generally, there is positive effect of openness and negative effect on income growth, which reproduces the results in Das (2009). Nevertheless, the effect is only significant in the non-oil sample. Although OLS estimation is still BLUE and consistent under possible multicollinearity, we need more observations to get more precise estimators.

The diagnostic test of residuals in Table III shows the variances are not under- estimated since we cannot reject the null of heteroscedasticity. Furthermore, there is no nonlinearity since the coefficient of any extra nonlinear term, such as $(\ln \hat{y}_j)^2$, is insignificant.

TABLE IV: Chow Structure Stability Test with Cross-Section Data, 1970-2009

	F-statistic	Log likelihood ratio	Wald Statistic
(1) Structure Change for OECD	0.753059	3.142311	3.012238
	(0.5575)	(0.5343)	(0.5558)
(2) Structure Change for EM	5.587220***	21.94160***	22.34888***
	(0.0003)	(0.0002)	(0.0002)
(3) Structure Change for $ln(y_{70})$	0.354339	1.486397	1.417356
	(0.8407)	(0.8290)	(0.8412)
(4) Structure Change for $ln(s)$	0.980788	4.080308	3.923153
	(0.4200)	(0.3952)	(0.4165)
(5) Structure Change for $ln(n+g+\delta)$	2.164864*	8.869094*	8.659454*
	(0.0757)	(0.0645)	(0.0702)
(6) Structure Change for openness	3.569023***	17.98808***	17.84512***
	(0.0045)	(0.0030)	(0.0031)
(7) Structure Change for government intervention	3.172823***	16.08993***	15.86411***
	(0.0095)	(0.0066)	(0.0072)

Note: *(1) The F-statistic, likelihood ratio and Wald statistic are report with the p-value in parentheses;*

(2) $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$*;*

(3) NONOIL sample is used in the Chow tests;

(4) The Chow tests for (1)-(5) are based on the regression

$\Delta ln\hat{y}_i(t) = \beta_1 ln(s_i) + \beta_2 ln(n_i + g_i + \delta_i) + \gamma\, ln\, \hat{y}_i(t_1) + \varepsilon_i$*. The Chow tests for (6) is based on the regression* $\Delta ln\hat{y}_i(t) = \beta 1 lnsi + \beta 2 lnni + gi + \delta i + \beta 3 opi + \gamma lnyit1 + \varepsilon i$*. The Chow tests for (7) is based on the regression*

$\Delta ln\hat{y}_i(t) = \beta_1 ln(s_i) + \beta_2 ln(n_i + g_i + \delta_i) + \beta_3 gov_i + \gamma\, ln\, \hat{y}_i(t_1) + \varepsilon_i$*;*

(5) The structural breakpoint in (3)-(7) is tested for the first 100 countries vs the last 57 countries in the order of the particular explanatory variable.

Last but not least, Chow structural stability tests are summarized in Table IV. Though there is no evidence of structure change in OECD or countries with a higher initial income level or higher saving ratio, emerging markets and countries with different degrees of openness and government intervention differ significantly in the convergence structure. The result for countries with higher population growth is mixed.

3.3 Panel Data Analysis

Pooled OLS (PA) regression in Table V shows that the implied convergence rate is quite similar with the cross-section result. Moreover, the pattern that $\lambda_{EM} > \lambda_{OECD} > \lambda_{NONOIL}$ still holds. Thus, the five-year averaging is justified.

TABLE V

Pooled Panel Data (PA) Test for Conditional Convergence, 1970-2009

Dependent Variable is log difference GDP per capita between 5-year period: $\Delta ln(y_{it})$

Sample	NONOIL			OECD			EM		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(y_{it-5})$	-0.034***	-0.035***	-0.044***	-0.051***	-0.067***	-0.070***	-0.096***	-0.098***	-0.098***
	(0.007)	(0.007)	(0.007)	(0.015)	(0.015)	(0.017)	(0.021)	(0.022)	(0.021)
$ln(s_{it})$	0.080***	0.073***	0.087***	0.248***	0.240***	0.229***	0.174***	0.168***	0.166***
	(0.010)	(0.011)	(0.010)	(0.033)	(0.031)	(0.038)	(0.031)	(0.032)	(0.031)
$ln(n_{it}+g+\delta)$	-0.048***	-0.048***	-0.050***	-0.005	-0.001	-0.025	0.006	0.002	-0.022
	(0.011)	(0.011)	(0.011)	(0.018)	(0.017)	(0.021)	(0.036)	(0.036)	(0.038)
op_{it}		0.031*			0.060***			0.017	
		(0.015)			(0.017)			(0.022)	
gov_{it}			-0.371***			-0.464*			-0.437
			(0.059)			(0.205)			(0.226)
N	986	986	986	171	171	171	144	144	144
Wald test	58.28	54.68	53.79	22.48	20.33	22.71	10.59	8.48	7.83
Joint Sig.	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.060)	(0.132)	(0.167)
Implied λ	0.00692	0.00713	0.00900	0.01047	0.01387	0.01451	0.02019	0.02063	0.02063

Note: (1) standard errors in parentheses;

*(2) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;*

(3) H_0: all coefficients of year dummies are equal to zero in the Wald test. χ^2 statistics is reported with p-value in parentheses;

(4) Implied convergence rate $\lambda=-ln(1-\gamma)/5$;

(5) Country fixed-effect and year fixed-effect are included in the regression, but not reported.

If we assume $\{v_i\}$ is correlated with other explanatory variables, then the random effect (RE) and PA estimators are inconsistent. Hausman tests in Table VI reject the null hypothesis that difference in RE and fixed effect (FE) coefficients is not systematic. Hence we should use the FE estimator.

TABLE VI
Fixed-Effect Panel Data (FE) Test for Conditional Convergence, 1970-2009
Dependent Variable is log difference GDP per capita between 5-year period: $\Delta ln(y_{it-5})$

Sample	NONOIL			OECD			EM		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(y_{it-5})$	-0.212***	-0.220***	-0.212***	-0.216***	-0.227***	-0.221***	-0.230***	-0.215***	-0.236***
	(0.019)	(0.019)	(0.019)	(0.043)	(0.041)	(0.040)	(0.038)	(0.038)	(0.038)
$ln(s_{it})$	0.107***	0.093***	0.107***	0.345***	0.322***	0.283***	0.144***	0.165***	0.129**
	(0.016)	(0.017)	(0.016)	(0.051)	(0.049)	(0.049)	(0.040)	(0.041)	(0.040)
$ln(n_{it}+g+\delta)$	-0.032*	-0.029	-0.035*	-0.010	-0.006	-0.036	-0.030	-0.054	-0.048
	(0.016)	(0.016)	(0.016)	(0.027)	(0.026)	(0.026)	(0.065)	(0.065)	(0.065)
op_{it}		0.072**			0.192***			-0.071	
		(0.027)			(0.047)			(0.038)	
gov_{it}			-0.586***			-1.923***			-0.645
			(0.117)			(0.406)			(0.365)
N	986	986	986	171	171	171	144	144	144
R^2	0.233	0.240	0.257	0.475	0.534	0.551	0.324	0.344	0.342
Wald test	16.76	13.26	13.89	5.57	3.13	4.79	3.49	4.16	2.90
Joint Sig.	(0.000)	(0.000)	(0.000)	(0.000)	(0.011)	(0.001)	(0.006)	(0.002)	(0.017)
Hausman	121.57	127.03	118.68	19.98	29.70	34.50	22.46	26.14	23.24
Test	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Implied λ	0.04765	0.04969	0.04765	0.04867	0.05150	0.04995	0.05227	0.048414	0.05384

Note: (1) standard errors in parentheses;

*(2) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;*

(3) H_0: all coefficients of year dummies are equal to zero in the Wald test. F statistics is reported with p-value in parentheses;

(4) H_0: there is no systematic difference between FE and RE estimators in the Hausman test. χ^2 statistics is reported with p-value in parentheses;

(5) Implied convergence rate $\lambda=-ln(1-\gamma)/5$;

(6) Country fixed-effect and year fixed-effect are included in the regression, but not reported.

Table VI shows a much higher convergence rate, which is around 0.05 among all samples regardless of openness and government intervention. Thereby, the economy moves halfway to its steady state in around $hl=-ln(0.5)/0.05= 13.9$ years, which is much shorter than hl_{OLS}.

Second, the estimations of openness and government intervention are more significant and precise. For OECD countries, if we hold initial real income and other factors fixed, then a one percentage point increase in the openness ratio will increase the growth over a three-year span by 0.192%, or 0.064% per year. Given the high volatility of international trade, this is not a trivial magnitude. Yet, the adverse effect of government intervention is even larger; its partial effect on growth is 0.641% per annum. It suggests that higher openness and a smaller

government facilitate a higher growth rate, which leads to faster convergence to its long-run steady state. The results are consistent with cross-section analysis.

Third, we find a significant effect of lagged log-value of openness on growth in the emerging markets

$$\Delta \ln y_{it} = -0.17 \ln y_{i,t-3} + 0.10 \ln(s_{it}) - 0.09 \ln(n_{it} + 0.05) + 0.08 \ln op_{i,t-3} + \eta_t + \mu_i + \varepsilon_{it}$$
$$(0.031) \qquad (0.041) \qquad (0.065) \qquad (0.036)$$

Owing to economic reform or industrialization, it is possible that EM have to change the economic mechanism and infrastructure before they could fully exploit the competitive advantage in later periods.

Under the Gauss-Markov assumptions of linearity, random sampling, full rank, erogeneity of the independent variables, both FE and first-differencing (FD) estimators are unbiased and consistent (Wooldridge 2002). Let us denote FD residual $r_{it}=\Delta\varepsilon_{it}$, and regress $r_{it}=\rho r_{it-1}+e_{it}$. If $\rho=0$, it implies $\{\varepsilon_{it}\}$ follows a random walk and FD is more efficient; if $\rho=-0.5$, namely $\{\varepsilon_{it}\}$ is uncorrelated, then FE is more efficient (Wooldridge 2009). Table VII shows all the convergence rates implied by FD are much larger than FE estimators. Nevertheless, both FE and FD reveal a higher convergence rate than cross-section regression.

TABLE VII
Fixed-Differencing Panel Data (FD) Test for Conditional Convergence, 1970-2009
Dependent Variable is difference of log difference GDP per capita over 5 year: $\Delta^2 ln(y_{it})$

Sample	NONOIL			OECD			EM		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta ln(y_{it-5})$	-0.597***	-0.600***	-0.592***	-0.493***	-0.490***	-0.460***	-0.458***	-0.442***	-0.457***
	(0.032)	(0.031)	(0.031)	(0.062)	(0.060)	(0.058)	(0.063)	(0.064)	(0.062)
$\Delta ln(s_{it})$	0.051**	0.034	0.053**	0.469***	0.465***	0.349***	0.275***	0.292***	0.244***
	(0.019)	(0.020)	(0.018)	(0.051)	(0.050)	(0.055)	(0.046)	(0.047)	(0.048)
$\Delta ln(n_{it}+g+\delta)$	-0.014	-0.012	-0.016	-0.026	-0.025	-0.036	-0.051	-0.080	-0.064
	(0.017)	(0.017)	(0.017)	(0.031)	(0.030)	(0.029)	(0.069)	(0.072)	(0.069)
Δop_{it}		0.087**			0.171*			-0.089	
		(0.032)			(0.068)			(0.065)	
Δgov_{it}			-0.779***			-2.222***			-0.914
			(0.137)			(0.502)			(0.491)
N	801	801	801	142	142	142	119	119	119
R^2	0.377	0.383	0.401	0.727	0.740	0.762	0.493	0.502	0.509
t Test	0.014	0 .019	0.021	-0. 111	-0.097	-0.093	-0.157	-0.173	-0.146
	(0.700)	(0.603)	(0.565)	(0.003)	(0.009)	(0.018)	(0.000)	(0.000)	(0.000
Implied λ	0.18176	0.18326	0.17930	0.13585	0.13467	0.12324	0.12250	0.11668	0.12213

Note: (1) standard errors in parentheses;

*(2) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;*

(3) H_0: $\rho=0$ in $r_{it}=\rho r_{it-1}+e_{it}$ in the t-test. t statistics is reported with p-value in parentheses;

(4) Implied convergence rate $\lambda=-\ln(1-\gamma)/5$;

(5) Country fixed-effect and year fixed-effect are included in the regression, but not reported.

In fact, Caselli (1996) proves that both FE and FD estimators are biased and inconsistent due to the endogeneity once lagged regressors are introduced ($\mathrm{Cov}(\ln y_{it-1} - \overline{\ln y_i}, \varepsilon_{it-1} - \bar{\varepsilon}_i) \neq 0$ and $\mathrm{Cov}(\ln y_{it-1} - \ln y_{it-2}, \varepsilon_{it-1} - \varepsilon_{it-2}) \neq 0$). One solution to the endogeneity is to use GMM that requires alternative assumptions of weak exogeneity and the identification of instruments--lags of $ln(y_{it})$ (Cameron, 2009). Another issue is about causality. Only through the Granger test in the panel data, can the causality between growth and saving, population, openness and government intervention be convincingly justified.

4. CONCLUSIONS

The study shows that unconditional convergence only exists in OECD countries, whereas conditional convergence to the steady-state occurs in 157 non-oil-producing countries, 28 OECD countries and 23 emerging markets. Moreover, we find higher growth rate and hence faster convergence with higher openness and lower government intervention in both cross-section and panel data analysis.

The convergence speed is the fastest in emerging markets, and slowest in non-oil-producing countries according to cross-section analysis. Yet, in panel-data analysis, the convergence speed is generally much faster; that is, it only takes decades for the country to move halfway to its steady state. The convergence structure differs between emerging markets and the rest of the world. Countries with higher openness and greater government intervention also have different convergence equations.

The cross-section is open to the doubt of omitted variable bias and ensuing endogeneity, whereas panel-data analysis also faces the issue of endogeneity once the lagged dependent variable is introduced. Further work could use the possible solution of GMM in the panel-data analysis.

REFERENCE

[1] Dowrick S. and DeLong J. B., 2001, Globalization and convergence, Paper for *NBER Conference on Globalization in Historical Perspective*, Santa Barbara, California.

[2] Barro, R. J., 1991, Economic growth in a cross-section of countries, *Quarterly Journal of Economics* 106, 407-443.

[3] Baumol, W. J., 1986, Productivity growth, convergence and welfare: What the Long-run Data Show, *American Economic Review* 76, 1072-1085.

[4] Cameron, A. C. and Trivedi P. K., 2009, Microeconometrics Using Stata, Stata Press.

[5] Caselli, F., Esquivel G. and Lefort F., 1996, Reopening the convergence debate: a new look at cross-country growth empirics, *Journal of Economic Growth 1*, 363-389.

[6] Chatterji M., 1992, Convergence clubs and endogenous growth, *Oxford Review of Economic Policy 8*, 57-69.

[7] Das R. U.， 2009, Imperatives of Regional Economic Integration in Asia in the Context of Developmental Asymmetries: Some Policy Suggestions, *ADBI Working Paper Series*.

[8] Islam, N. , 1995, Growth empirics: a panel data approach, *Quarterly Journal of Economics* 110, 1127-1170

[9] Mankiw, N. G., Romer D. and Weil D. N., 1992, A contribution to the empirics of economic growth, *Quarterly Journal of Economics* 107, 407-437.

[10] Romer, D., 2001, *Advanced macroeconomics*, 2nd edition, McGraw Hill.

[11] Summers, R. and Heston, A., 1988, A New Set of International Comparisons of Real Product and Price Levels Estimates for 130 Countries, 1950-85, *Review of Income and Wealth*, 34, 1-26.

[12] Wooldridge, J. M., 2002, *Econometric Analysis of Cross Section and Panel Data*, MIT Press.

[13] Wooldridge, J. M. (2009), 'Introductory Econometrics: A Modern Approach' (4th edition), South-Western.